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Known and Potential Impacts of Physical Disturbance From Maneuver Training on Threatened and Endangered Species

by
Ann-Marie Trame

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This research describes known impacts to TES resulting from military training, describes potential impacts to TES by reporting impacts from similar activities such as recreational use, and generally identifies gaps in current knowledge about the impact of military training on TES to encourage future research.

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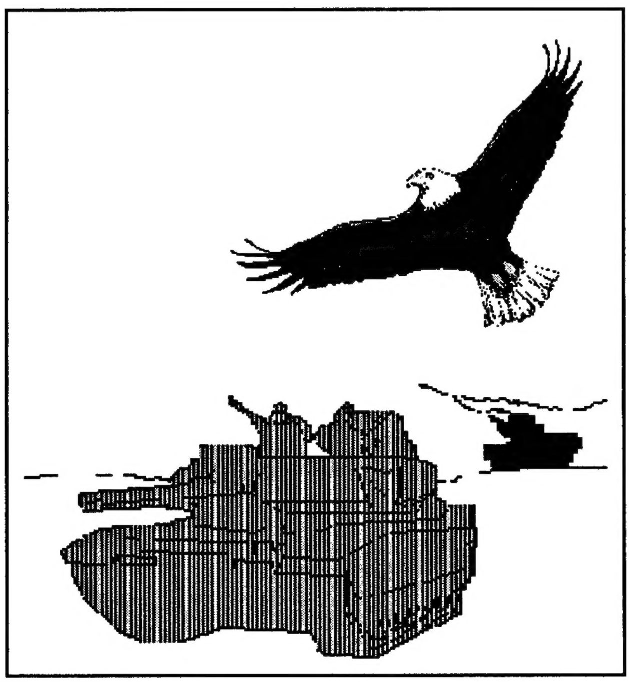

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Executive Summary

Threatened and endangered species (TES) are those species that the United States is most in danger of losing. Although Army land managers may have not purposefully protected rare species in the past, conversion of the natural landscape for agricultural and urban uses is less pervasive on Army installations than on the surrounding landscape. Consequently, large amounts of natural habitat remain intact, and rare species exist to a remarkable extent, even where heavy military training occurs.

There has been very little field research directed at identifying and quantifying possible impacts to TES from the physical disturbances related to maneuver training activities. However, in order to adequately conserve TES without needlessly hampering the military mission, managers need to know what impacts are significant. This report serves as an introduction to the known and potential impacts that result from physical disturbances related to maneuver training activities.

Dismounted training maneuvers most commonly cause soil compaction due to intensive trampling. The greatest impacts occur from occupation-of-area exercises (bivouacking), in which many people, vehicles, and activities are concentrated in a small area. The damage to soils and vegetation is similar to that from recreational camping. In general, soil becomes compacted, and ground cover, understory shrubs, and young trees are removed. In most cases, such modification in habitat will favor disturbance-tolerant, "weedy" species, and will not be suitable for plant or animal TES. There is also evidence that recreational camping and other outdoor activities can affect the behavior, reproduction, and population sizes in birds; little information exists for bivouac or camping impacts on other taxa.

Impacts can be minimized by reducing the size of the area that becomes altered. In many cases, a limited number of bivouac sites on fertile, well-drained soils covered with abundant grasses would be preferred over numerous sites managed with rest-recovery schedules. Long-term coordination between trainers and land managers can improve TES habitat in some areas and encourage future training sites to be moved to different areas to avoid impacts. When spatial conflicts cannot be avoided, adjustments in timing of military activities may reduce negative impacts. When

damage to soils and vegetation does occur, aggressive restoration efforts may prevent cascading impacts to surrounding areas.

Mounted (mechanized) training maneuvers impart more severe damage to soils and vegetation than do dismounted activities. Impacts are similar to those seen by recreational off road vehicular traffic. Soil compaction can occur to such an extent that the surface becomes sealed to water infiltration. Gully, sheet, and rill erosion are common and lead to sedimentation impacts in lower areas and surface waters. Vegetation can be totally removed by vehicular training. These impacts can be long-lasting. In general, grasses and mature trees are the most resistant to damage by mechanized training, while lichens, mosses, and shrubs tend to be very sensitive. These differences in tolerance lead to changes in plant community structure and composition, which creates different habitat available for animals. There has been much research to describe the indirect effects on animal species when habitat alterations occur from off road vehicles. In general, species that are adapted to reduced vegetation, bare ground, and/or disturbance are favored, while those who depend on certain native plants, dense ground cover, mature forests or little human presence decline. Some TES belong to the former group, others belong to the latter.

There is mixed evidence for direct behavioral impacts on animals. Most species that have been studied show avoidance behavior to mechanized activity, however, there is ample evidence for habituation as well. It is possible that behavioral response may be dependent on other factors, such as breeding activity, food availability, distance to shelter, etc.

The most effective way to reduce damage to soils and vegetation is to train on sites that have durable soils, little surface water, and hardy vegetation. If TES are not compatible with disturbance, compromises between training needs and TES requirements may be necessary. Wise placement of and long-term planning for training sites and future TES habitat sites can reduce conflicts. Impacts can be disproportionately severe when soils are very wet or very dry (in desert areas). By minimizing maneuver training under those conditions, a small change in the training regime may lead to large benefits. Despite all efforts, the operation of heavy machinery in cross-country training will always lead to damage and habitat alteration. Natural resource staff must aggressively manage the resulting erosion, so effects are locally restricted, and try to protect surface water resources from sedimentation. In many cases, avoidance of high quality TES habitat through long-term planning and compromise may be the only way that mechanized training can continue to co-exist with TES on military installations.

Avoidance of conflict may be the only way to mitigate impacts from earth-moving activities. Large-scale engineer training disrupts the soil layers to such a degree that revegetation may be impossible. Many installations protect their natural resources by limiting this training to a single designated site. When foxholes and tank pits are dug in conjunction with maneuver or land-occupation exercises, the soil layers should be replaced as carefully as possible so revegetation by colonizing species can stabilize the soils and reduce erosion impacts.

Overall management of TES is based on maintaining viable populations across a landscape through time. Habitat needs are determined according to numbers of individuals, habitat quality, home range size, migration patterns, and interactions with other species. It is important to maintain connected habitat for a variety of reasons. In many or most cases, the amount and distribution of habitat is more important than impacts to individuals. By reducing habitat fragmentation, especially of high quality habitats on the installation, master planners can probably make the greatest contribution towards managing TES in concert with effective military training.

Foreword

This study was conducted for the Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS) under the ODCSOPS Study Program, Military Interdepartmental Purchase Request (MIPR) No. E87930341, dated June 1994, work unit KW3, "Effects of Army Training on the Management of Endangered Species on Army Training Lands and Ranges." The technical monitors were Pete Waas, Tom Macia, and Anthony Rekas, DAMO-TRO.

The work was performed by the Natural Resource Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). Part of the work was performed through the appointment of Ann-Marie Trame to the Research Participation Program at USACERL administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and USACERL. The USACERL principal investigator was Dr. David J. Tazik. Dr. Tazik is Acting Chief, CECER-LL-N, and Dr. William D. Severinghaus is Operations Chief, CECER-LL. The USACERL technical editor was Gloria J. Wienke, Technical Resources Center.

COL James T. Scott is Commander of USACERL, and Dr. Michael J. O'Connor is Director.

Contents

1 Introduction

Background

To achieve and maintain military preparedness, the U.S. Army uses more than 11 million acres of land throughout the United States. These lands and their natural resources have always provided tangible benefits to the Army and to the nearby public: realistic training environments, the buffering of neighboring lands from Army activities, resources such as timber and game, and recreational opportunities. Army lands have sustained these benefits through natural resource management, or land management. In the past, the primary goal of land management was to supply products and services that directly and obviously benefit people, such as those listed above.

Since the early 1970's, natural resource management has become increasingly influenced by societal concerns for conserving all native species of plants and animals, regardless of their known or immediate usefulness to human enterprise. The United States became the global leader in conservation when the Endangered Species Act (ESA) of 1973 was passed. The act granted substantive protection from extinction to all listed flora and fauna. The continued existence of a species on public land cannot be jeopardized once it is listed as "threatened" or "endangered" under the ESA.

Threatened and endangered species (TES; both listed and candidate species) are species that the United States is most in danger of losing. Although Army land managers may not have purposefully protected rare species in the past, conversion of the natural landscape for agricultural and urban uses is less pervasive on Army installations than on the surrounding landscape. Consequently, large amounts of natural habitat remain intact, and rare species exist to a remarkable extent, even where heavy military training occurs.

Very little field research has been directed at identifying and quantifying possible impacts to TES from the physical disturbances related to maneuver training activities. However, to adequately conserve TES without needlessly hampering the military mission, managers need to know what impacts occur. This report describes

the known and potential impacts that result from physical disturbances related to maneuver training activities.

This report is written for the military training community and serves as an introduction to the ecological processes that can lead to impacts on sensitive species. It is hoped that an increased information base about how impacts can occur will assist trainers in decisionmaking and planning to mitigate impacts, and to encourage communication between the natural resource community and the training community at both the Major Command (MACOM) and installation levels.

Objectives

The objectives of this work are to: (1) describe known impacts to TES resulting from military maneuver training; (2) describe potential impacts to TES by reporting impacts from similar (analogous) activities, such as recreational land use; and (3) generally encourage future research to fill in the gaps in current knowledge about military maneuver impacts to TES.

Scope

Instead of focusing on individual species issues, this report broadly reviews the general changes to soils and vegetation that occur from maneuver training, and discusses how those changes are known to affect plants and animals. Available information from all species is used to make conclusions pertinent to TES conservation. This review is not limited to any region of the country or taxon, although it is constrained by the available information base.

Approach

This work effort was a literature review. When very little research was found on TES, the review was broadened to include other species as well as impacts to soils and vegetation. Thus, information about potential impacts to TES is generated from extrapolation and general ecological theory instead of from quantitative data.

2 Potential Maneuver Training Impacts

Dismounted Troop Maneuvers

Dismounted training occurs during portions of training exercises when soldiers are on foot. Activities may include patrolling, cross-country skiing, navigation, marching, and land-occupation activities (bivouacking). Bivouacking occurs anytime a unit stops to set up security, rest soldiers or equipment, construct fighting positions, camouflage vehicles and equipment, or stay in one place for any length of time. Bivouacking produces impacts that are generated by vehicle activity, foot traffic, digging, etc. (Department of the Army [DA] 1993). Firing points and other areas where troops gather can experience the same effects. Impacts on natural resources can be similar to those generated in public campgrounds or along hiking and cross-country ski trails.

Impacts on Soils

The impact of dismounted troop activities on soils has not been widely researched. However, Trumbull et al. (1994) examined changes to soils in bivouac sites on Fort Leonard Wood, MO. They found soil losses of up to 60 cm, but found no change in infiltration rates (which generally decrease with soil compaction, see below).

The effects of hiking, camping, and other recreational activities on soil resources can be generally applied to military dismounted training. Most recreational damage occurs through trampling of the soil. Heavily used areas will suffer from soil compaction (Marion and Merriam 1985), which increases soil density and decreases soil porosity by reducing the spaces between soil particles that normally hold air. Decreased soil porosity lowers water infiltration rates, thus increasing erosion and runoff from the area, especially if the area is sloped. Severe compaction can reduce the amount of oxygen available in the soil. These physical changes inhibit plant germination and negatively affect plant growth and survival (Kuss and Graefe 1985; Cole 1987). Since vegetation adds nutrients and organic matter to soil and helps to prevent erosion, loss of vegetation will further reduce soil fertility and increase erosion.

Impacts on Vegetation

Damage from troop maneuvers or recreational camping is caused by direct trampling or clearing of vegetation (U.S. Army Corps of Engineers [USACE] 1994; Michigan Department of Military Affairs [DMA] 1994; Cole 1987), as well as through changes in soils. Trampling reduces the physiological and cellular activity of plants, leading to effects that are similar to disease or nutritional stress (Kuss and Graefe 1985). This reduced activity was demonstrated in a northwestern Ontario campground, where increases in soil compaction and decreases in litter depth and infiltration rates were tightly linked to decreased growth in jack pine (James et al. 1979). However, reduced growth in canopy species was not found by Trumbull et al. (1994). Other potential effects include reduced vigor and reproduction (Cole 1987).

High levels of trampling eliminate vegetation. Trumbull et al. (1994) documented a 57 percent decrease in woody stem density, a 72 percent decrease in understory cover, and an increase in bare ground (from 2 to 17 percent). Canopy cover was reduced for height classes of 0.6 to 1.0 m (Trumbull et al. 1994). James et al. (1979) documented the loss of all vegetation except mature trees. Garton, Hall, and Foin (1977) found a decrease in plant abundance for plants less than 25 ft tall, loss of foliage less than 20 ft high, and a 49 percent increase in bare soil due to recreational camping. Blakesley and Reese (1988) found lower shrub, sapling, and tree densities in campground sites vs. noncampground sites in northern Utah.

Loss of vegetation due to recreational trampling can increase soil surface temperatures, leading to localized drought and desiccation. In fine-textured soils, increased microclimate temperatures and increased evaporation rates led to the formation of crusts that inhibited water absorption and seedling emergence (Kuss and Graefe 1985). These changes can lead to population declines of native plants, simplification of vegetation, and loss of habitat diversity for the animals that rely on those plants (reviewed in Boyle and Sampson 1985). Harsh environmental conditions, along with the changes in soil structure that simultaneously occur due to trampling, favor species tolerant of moisture and oxygen stress. Early successional species, very sturdy species, and/or disturbance-adapted species are favored, thus changing the plant community composition and structure of the area (McDonnell 1981, Cole 1987, Tazik et al. 1992) such that native species richness and species diversity decline (Cole and Landres 1995). In general, grasses and sedges are more resistant to damage, while low shrubs, tree seedlings, and lichens are very susceptible (Cole 1987).

At Camp Grayling, MI, for example, bivouacking creates open wooded areas, with little vegetation or brush, which increases wind erosion. Community structure

differs dramatically in naturally vegetated areas (Michigan DMA 1994). Although woody vegetation at Fort Leonard Wood did not show evidence of conversion to trampling-resistant species, woody understory species richness declined by 33 percent while species evenness increased (Trumbull et al. 1994). Heavier recreational use in northwestern Ontario led to more homogenous vegetation than is natural and reduced recolonization by original species. Plants that would not naturally exist there became successful invaders. They were characterized by short stems; small, flattened, narrow or basal leaves; and the ability to produce many seeds while stressed. Original species that remained were characterized by a dwarfed growth habit (James et al. 1979). Change in species composition is greatest when native plants are susceptible to trampling and trampling-resistant invaders are available (Cole 1987).

Vegetational changes can persist for decades. After a period of 36 years, areas that were used as tent sites in the Mojave Desert still support 27 percent fewer plants and 29 percent less cover than adjacent control sites (Lathrop 1983a). Effects may not last as long in more moist, fertile ecosystems, but complete, rapid recoveries are not likely.

Trampling can also affect the plant community near frequently used footpaths. Within 1 to 2 meters of the edge of the trail, the plant community is altered. Some species, especially those adapted to the forest floor, are eliminated. Disturbance-tolerant and trampling-tolerant species increase. Some species invade the areas near, but not immediately adjacent to, trails. Beyond this 1- to 2-m trail border, minimal effects are seen on native vegetation (Dale and Weaver 1974).

At many Army installations, dismounted training occurs year-round, including while snow is on the ground. Plants can still be negatively impacted from trampling while snow covers them, although more snow offers greater protection (DA 1993).

Impacts on Animals

Listed animal populations can be reduced indirectly by damage to soils and vegetation, leading to altered plant communities, which may be unsuitable as habitat for the animals that once used them. Unfortunately, this phenomenon is not well researched. Impacts are probably substantial for some species, but not rigorously documented (Cole and Landres 1995). The Camp Grayling Environmental Impact Statement (EIS; Michigan DMA 1994) describes the open understory found in bivouac sites and firing points compared to the moderate-dense understory found in areas without foot traffic. In most cases, anthropogenic modification of a forest will favor early-successional animal species over native interior animal species (DA

1994). For example, Guth (1978) found that campgrounds had a higher density of birds than the unmodified forests, but also had a higher percentage of widespread, common, and human-adapted species, while numerous rare forest species were absent.

Sometimes, listed animals will require a specific plant species or community as a resource, so destruction of the vegetation affects the animals. Gopher tortoises will not thrive near a bivouac site since most of the vegetation will eventually be removed, and the tortoises depend on grasses and forbs relatively close to their burrows (DA 1988). Similarly, the Black-capped Vireo (BCV) is affected by dismounted training maneuvers. The BCV nests within 1 meter of the ground, so the birds are susceptible to direct nest damage during the breeding season, as well as to the loss of adequate nest sites through vegetation removal (Tazik et al. 1992, USACE 1994). One study found that birds breeding in campground areas were tree nesters, while those species found in noncampground areas were more likely to nest on the ground, in shrubs, or in very small trees (Blakesley and Reese 1988).

Dismounted military training and similar recreational activities can have direct disturbance effects on animals. There are three learned responses to a stimulus such as human activity: avoidance (due to negative effects), attraction (due to positive effects) and habituation (due to a neutral interaction; Knight and Temple 1995). Military training impacts most likely result in avoidance behavior of sensitive animals. It is thought that noise and the physical presence of humans can cause nest abandonment in Black-capped Vireos (Tazik et al. 1992) and den or young abandonment in the San Joaquin Kit Fox (EG&G Energy Measurements, Inc. [EG&G/EM] 1991) and the black bear (Goodrich and Berger 1994). Yalden and Yalden (1990) documented the flushing behavior of nesting golden plovers. They found that the longer people remained in the area, the longer it took for the birds to return to their nests. Disruption of normal behaviors was more common after chicks had hatched, compared to the incubation period. Burger (1981) documented that faster, closer movements, such as jogging, disturbed shorebirds more than walking or clamming activity. MacArthur, Geist, and Johnston (1982) documented increased heart rates in mountain sheep in response to vehicles, humans on foot alone, or humans on foot accompanied by a dog. Stress and avoidance were significantly lower when a common stimulus was presented vs. a novel stimulus; habituation to vehicles on a nearby road was evident (MacArthur, Geist, and Johnston 1982).

Behavioral disruptions such as flushing can lead to increased predation on chicks (Kury and Gochfeld 1975; Flemming et al. 1988) or the displacement and death of eggs (Ames and Mersereau 1964; Anderson and Keith 1980). When disturbed by humans on foot, humans in a vehicle, a gas operated engine, and the sound of a rifle,

fewer ferruginous hawks had successful nests, and fewer young fledged from those nests (White and Thuron 1985). In contrast, no evidence was found that human activities decreased breeding bald eagles' reproduction, even though behavioral avoidance was documented (Fraser, Frenzel, and Mathisen 1985).

Impacts on reproductive success can translate into decreased populations (Anderson 1995). Increased human presence on beaches has been correlated with decreased shorebird abundance (Pfister, Harrington, and Lavine 1992). In another study, 8 out of 13 woodland breeding bird species showed a negative correlation between population density and recreational intensity (van der Zande et al. 1984). Furthermore, fewer wintering bald eagles were found in areas with high human activity compared to areas with moderate human activity. The presence of humans appeared to disturb eagles the most while they were feeding, and caused a shift in their distribution to marginal habitats (Stalmaster and Newman 1978), where reproductive success could be lowered.

Management and Mitigation Options

Although abundant data do not exist regarding the impacts of dismounted training on soils, vegetation, animals, or TES, much of the available research is in agreement. It can be surmised that effects documented in the recreational literature are representative of potential training impacts. Biological Assessments (BAs) and EISs prepared for training land activities to date also suggest that disturbance has direct effects. Mitigation actions can be implemented to reduce the magnitude of these potential impacts. Although training requirements and local environmental conditions must be considered, some general options exist to reduce the negative impacts of dismounted military training.

One of the most powerful management option events, especially over the long term, is to control the locations and timing of training and to influence the locations of TES populations as much as possible. The ability of the land to sustain training activities can be considered; damage can be minimized by not exceeding the land's capacity to withstand activity and by repairing impacts that do occur. This approach is most frequently used to avoid significant or permanent damage to soils and vegetation. Some land is inherently more resilient than other land. That with the highest capacity to sustain recreational activities is known to have the following characteristics:

- fertile, well-drained soils, especially sandy loams, fine sandy loams, and loams (Cole 1987),
- slopes facing the north, east, and northeast,

- vegetation with small, leathery leaves, or an abundance of native grasses,
- species that are tolerant of human activity, and
- light tree cover, which allows more grass in the understory (Chubb and Ashton 1969).

Methods to quantify carrying capacity on military lands is an important, ongoing policy and research effort in the Integrated Training Area Management (ITAM) program. Such criteria could be used by master planners to locate bivouac and assembly areas on durable pieces of land. In addition, smaller-scale opportunities exist to use the same principle when they do not conflict with military doctrine.

The timing of dismounted military activities can affect how much damage occurs. The capacity of most land is compromised in the early growing season, when soils are generally wet, and plant growth is in a vulnerable and critical stage of new growth. A relatively small reduction in training at that time may produce comparatively large gains in soil and vegetation quality.

Besides understanding the capacity of the land for dismounted training activities, it is useful to know how to disperse activities through space and time in order to minimize the total area affected. The recreational literature suggests that when frequency of activity is very low, such as in backcountry campsites that are rarely used, it is best to encourage dispersed use, to minimize the impacts at any given site. However, when frequency of use is high, and large cumulative impacts are expected (which is much more likely in a military training scenario), activity should be concentrated in the most durable sites, to minimize the area of significant change to soil and vegetation. Rest-rotation schemes will only be effective when the time required to create the impact is longer than the time required to recover (Marion and Merriam 1985), so they may not be realistic for military bivouac sites. This conclusion can be found in the Camp Grayling EIS (Michigan DMA 1994), which calls for a limited number of bivouac sites. In addition, site durability can be increased through the use of gravel, geotextiles, and other erosion-control technologies (S. Warren, Research Scientist, USACERL, professional discussion, April 1994). Restricting the spatial distribution of land use and enhancing site durability are two of the most effective methods to mitigate impacts to soils, vegetation and animal habitat (Cole and Landres 1995).

While it is important to consider the general durability of training land, direct impacts on TES populations can be further avoided while training occurs. The Fort Hood, TX, BA (Tazik et al. 1992) makes this clear. Much overlap between important TES habitat and training can be avoided through planning. In almost all cases, the continued use of previously established training positions will not cause conflicts,

as long as no TES occupy the sites. These areas should be re-used as much as possible within the requirements of the military mission. To prevent future conflicts, currently or potentially important TES habitat may be avoided or restricted as training sites, while areas representing poor TES habitat can be considered for training, if appropriate.

In the long term, land managers can work with military trainers to encourage appropriate TES habitat in areas where training is less desired, while not encouraging TES habitat in areas that are needed for training. The Camp Grayling EIS (Michigan DMA 1994) and the Camp Shelby BA (DA 1988) mention similar strategies. To be effective, sufficient habitat must be provided for TES such that legal obligations under the ESA are met. This may be very difficult in some situations, since (1) pressures for more military training on less land will increase in the future and (2) we do not understand the needs of most TES well enough to determine critical habitat components or the minimum areas required for long-term survival. One example of our current level of knowledge is that techniques such as translocation of individual animals or plants, although promising, are not very dependable for most species at this point in time. For this reason, relocation is not always an acceptable mitigation technique to the Fish and Wildlife Service (FWS) under current implementation of the ESA. Long-term planning for habitat enhancement at the landscape/installation scale can strive to shift TES populations away from training lands, but other management and mitigation measures will be needed, especially in the short-term.

Sensitive areas, such as isolated, small plant populations or animal dens and nest sites, may be flagged and avoided during training. Fraser, Frenzel, and Mathisen (1985) caution that buffer zone distances should be determined on a site-by-site basis when dealing with direct disturbances to animal species. Clearing and fragmentation of TES habitat should be avoided whenever possible. Even when training is certain to coincide with TES habitat, adjustments in the timing or intensity of the activity may significantly reduce the conflict. Activities should be avoided in TES habitat during critical seasons for the species. Frequently, breeding seasons are important for animals, while the early spring growth stage is critical for plants. More detailed understanding of critical stages or times for a population can be acquired through ecological life history tables (Anderson 1995), a standard method of studying population dynamics. This type of research identifies the stage (or ages) of individuals that contribute the most to population growth and maintenance, and can be used to prioritize management of species. For example, trainers could improve predictions of the relative impacts of various training schedules, by knowing which individuals are most important to population survival and how different schedules affect those individuals. In addition to improved

predictions, an appropriate monitoring program would help recognize negative impacts early enough to allow implementation of effective mitigation measures.

Land that has been damaged by dismounted training usually can be restored through revegetation with resilient species, and closing the area until the plants become well established. In Texas, site closure of a few years' duration, along with rototilling plus bark and wood chip mulch, decreased soil compaction. Planting winter grasses decreased surface erosion (Legg, Farnham, and Miller 1980). In some cases, recovery of campsites can take many years, even decades (Cole 1987).

Mounted Troop Maneuvers

Mounted training occurs when troops practice maneuvers with wheeled and/or tracked vehicles. Movement occurs throughout the training area, including on slopes and hills, through streams, and near water. Since the terrain is used for concealment and protection, maneuvers that avoid open space, avoid open or high ground, or use depressions for concealment must be practiced (Field Manual [FM] 7-7). Due to the modern battlefield scenario, impacts from mounted training will occur over much larger areas than in the past; managing the impacts will be imperative, yet challenging.

Impacts on Soils

Severe erosion can occur from mounted training exercises; the potential damage is much greater than that caused by dismounted training activities. Erosion occurs from the detachment, translocation, and deposition of soil particles. Unfortunately, this cannot be prevented during mounted training, and the land is left even more vulnerable to the natural forces of further water and wind erosion (Michigan DMA 1994). Some of the factors reviewed by Thurow, Warren, and Carlson (1993) that affect damage and recovery of soils include: vegetation type, soil texture, soil moisture content, clay mineralogy, root growth, and soil microfauna. Research at Yakima Training Center, WA, compared rutting impacts at 10, 50, and 1000 passes in "dry-normal," "wet," and "wet-slippery" soil conditions for four military force configurations. Wet and wet-slippery conditions led to more and deeper ruts, as did a greater number of passes (O'Neil et al. 1990). Thurow, Warren, and Carlson (1993) concur that wet soils become eroded and compacted with fewer passes and for longer times than drier soils, and that increases in intensity of training is correlated with increased interrill erosion (Thurow, Warren, and Carlson 1993).

Just as in dismounted training, the removal of vegetation will exacerbate any impacts on soils. Tracked and wheeled vehicles do significant damage to vegetation during training maneuvers. The loss of vegetation will increase erosion, while it decreases soil porosity and permeability. The soil can become hard, rocky, and infertile as it dries. Soil temperatures become less stable. For all of these reasons, the soil becomes less habitable by plants, and conditions continue to deteriorate (Vachta and Riggins 1988). At the worst, maneuver training can cause extensive sheet erosion and intensive gully erosion, which remove all of the original soil. Damage of this severity can last for thousands of years, until the soil becomes reestablished. Until then, very few plant species are able to survive (Severinghaus, Riggins, and Goran 1979). Extreme measures, such as furnishing new topsoil directly, may be required to repair damage in these circumstances.

Another form of damage is soil compaction. The risk of compaction depends on the number of passes the vehicle makes (intensity), the weight of the machine, tire contact pressure, soil type, and moisture conditions. At 80 percent saturation, soils suffer peak compaction. At >80 percent saturation, there is no additional compaction, but the soil structure will be damaged and the surface will become "sealed" (DA 1994). In central Texas, increased intensity in tank traffic led to a 2-yr decline in infiltration rates on wet soils. There was no immediate significant increase in erosion, however. Only after 2 months, when the processes of soil shrinkage and swelling had loosened the soil surface, did erosion increase greatly (Thurow, Warren, and Carlson 1993). Damage may be long term. On a heathland in northern Europe, measurable effects in soil compaction, pH, nutrient content, and visible ruts were still present 19 years after tank training occurred in 1963 (Beije 1987).

The weight of the vehicle determines the degree of subsoil compaction. Deeper compaction caused by heavier machines has longer term effects. Different soils have varying capacities for damage from vehicle training. Soil properties such as bearing capacity (the ability to bear a load without settling or rutting) and traction capacity (ability to provide resistance against a moving vehicle without causing slippage) can reduce the depth of impacts (DA 1994). The Fort McCoy, WI, BA (DA 1993) reports that training impacts on that installation may disturb the top 2 to 3 in. of topsoil and may damage above-ground portions of plants, but do not damage deep root systems.

There may be unique impacts from military activities in arid environments. In some areas, the sparse desert vegetation may benefit from cyanobacterial-lichen soil crusts, which stabilize the soil surface against wind and water erosion, increase soil aggregation, increase plant seedling establishment and survival in some species, and fix nitrogen into a form accessible to nearby plants (Belnap, Harper, and

Warren 1994; references therein). The ability of these cryptobiotic crusts to fix nitrogen was significantly reduced 9 months after 1, 4, and 10 tank passes were experimentally applied to land in the Utah desert. During this time, the crusts appeared to have re-established themselves, so visual inspection is not always an accurate indicator of nitrogen fixation (Belnap, Harper, and Warren 1994). If this impact reduces the amount of available nitrogen over large areas for long periods of time, it could result in cascading effects on the ecosystem.

Off-road recreational vehicles (ORVs) create impacts similar to the wheeled vehicles used in mounted military training. The damage that is possible can be seen on the denuded hills where motorbikes and minibikes are used. Ruts at the edge of streams progressively break down until the bank collapses (Lodico 1973).

The U.S. Geologic Survey (USGS) determined that all soil types examined are vulnerable to ORV damage except for a few clay-rich soils on slopes of less than 10 percent. Sandy and gravelly soils tend to get stripped of vegetation and then suffer gully erosion. ORV use on most clay soils pounds the surface until it is sealed from water penetration; the increased runoff also can create gullies. Soil structure can be damaged too. Top layers get pulverized, while lower layers become so compacted they cannot support vegetation again (Sheridan 1979).

Some quantitative studies have documented soil impacts due to ORV use. One study compared the effects of 1, 10, 100, and 200 straight-line passes of motorcycles at a constant velocity in the Mojave Desert. After one pass, there was a visual path. After both 100 and 200 passes, berms formed along the path, and 10 to 30 mm of soil was displaced from the cycles' track. Soil compaction was significant in all four treatments. Compaction was greatest immediately below the soil surface. Higher speeds led to less compaction but greater soil displacement (Webb 1983).

At Land Between the Lakes, a hardwood forested recreational area, ORVs increased the erosion depth along trails 26 percent in 1 year. Sedimentation and siltation were noticeable problems below steep, heavily used slopes. ORV use in the Mojave Desert completely denuded 543 acres and severely damaged another 960 acres over a 10-year period. This type of damage will increase wind erosion and is a major cause of dust storms in the area. In the foothills of the San Gabriel Mountains, ORV damage to hills has buried productive grasslands downslope and increased erosion rates eight times (all data cited in Sheridan 1979).

Some installations conduct mounted training sessions year-round. Even though soils are generally frozen during winter months in northern areas, mounted training maneuvers can still produce effects. The greatest effect on soils is that snow

becomes compacted. This can delay thawing in the springtime, which may decrease runoff velocities and thus decrease erosion in the springtime, but can also cause the soil to freeze harder, more often, and deeper than beneath noncompacted snow (Sheridan 1979). Overall, snow compaction may have either positive or negative consequences.

Impacts on Vegetation

Mounted military training will unavoidably disturb plant life, and simultaneously compact and erode the soil such that reestablishment is difficult (DA 1975; reviewed in O'Neil et al. 1990). Most damage occurs from off-road movement (Michigan DMA 1994). Soil compaction and mixing of soil horizons leads to changes in air, water and nutrient content of soils, and changes in pH and infiltration rate. These alterations lead to reductions in germination, growth, and reproduction in native plants (Cole and Landres 1995), and changes in species composition and community structure (Beije 1987; Cole and Landres 1995).

Certain types of plants (early-successional, "weedy," and/or disturbance-adapted species) are more resistant to damage from physical disturbance and are more likely to recover from such disturbance (measured as "resilience"). Yorks et al. (1997) reviewed the characteristics of plants that are correlated with these two traits: resistance and resilience. They found resistance correlated with the following characteristics (strongest to weakest relationship): graminoids (grasses); trees; cryptophytes (nongrasses that regenerate from bulbs, corms or rhizomes) and forbs; thallophytes (liverworts, mosses and lichens); shrubs; and climbers. Characteristics correlated with resilience were: graminoids, cryptophytes, forbs and thallophytes; trees and shrubs; and cactoids. They also concluded that shrubs with tap roots may be more resilient than shrubs with fibrous, shallow roots. Annuals were found to be more resilient than perennials, deciduous woody species may be more resilient than evergreen, warm-season grasses may be more resilient than cool-season grasses, grasses with tillers were both more resistant and more resilient than others, while shade-adapted and rhizomatous species were more sensitive to damage (reviewed in Yorks et al. 1997). It is such differential sensitivity to damage from physical disturbance that causes alterations in community composition and structure due to mechanized military training.

Empirical evidence supports these generalizations. On Fort Hood, a control site had 1.7 times more trees (which provided 2.6 times more aerial cover and 2.5 times more basal cover) than a nearby maneuver site. The control site also had 3 times more small woody plants (shrubs) which covered 3.2 times more area. Training had also shifted the forb community from large perennial plants to small weedy annual

plants (Severinghaus et al. 1981). The most compacted soils at Fort Knox, KY, were found to support a community of disturbance-adapted species, such as camphor and *Lespedeza*, and grasses, probably a mix of *Andropogon* and *Setaria*. Other sites on the installation supported at least twice as many species in the herb layer (Severinghaus, Riggins, and Goran 1979). On Fort Benning, GA, tracked vehicle training has replaced native longleaf pine/turkey oak forest with old field communities (similar to what is seen when agricultural fields are abandoned; Goran, Radke, and Severinghaus 1983).

In the desert southwest, the relative intensity of Army training had a direct, proportional effect of decreasing the density, stem diameter, and height of the two dominant shrub species, while also decreasing the ground cover and increasing the amount of sandy substrate. In addition, the site with the most training use was characterized by cheesebush and other "weedy" species that are highly adapted to disturbed soils (Krzysik 1985).

The same pattern was found on Fort Lewis, WA, where training decreased plant cover but increased the number of individual plants (due to the loss of large perennials and the invasion of small annual "weeds"). In fact the entire composition of the flora was dramatically altered (and simplified) by training impacts. While the control site had 64.5 percent cover from introduced species, 56.6 percent cover from native vascular species, and 41.4 percent cover from nonvascular plants, the training site had 49.9 percent cover from introduced species, 15.5 percent cover from native plants, and 57.0 percent cover from nonvascular plants, mainly mosses (it is presumed that the remaining cover is in bare ground, but that is not directly explained; Severinghaus and Goran 1981). This kind of alteration is significant to TES conservation, because most listed threatened and endangered plants are native vascular plants. Reductions in native species can, in turn, lead to even more erosion unless weedy species successfully stabilize the soil (Stones, Downs, and Stewart 1987). In some cases, weeds cannot stop erosion, while native bunchgrasses effectively intercept overland flow of water (documented in central Texas; Thurow, Warren, and Carlson 1993).

How much training can occur before serious impacts are seen? One experiment controlled the timing (spring vs. summer) and the frequency (0, 4, 18, or 35 passes) of tanks driving over a Canadian prairie community (Wilson 1988). Increases in tank driving frequency led to detrimental changes in the plant community composition and to increases in percentage of bare ground. The study revealed different responses due to seasonality of the tank traffic, which led to recommendations for restricting tank training between spring thaw and July 1. Researchers also estimated the area needed to sustain a certain level of training, although results are

applicable only to evenly distributed, straight-line tank traffic, which is somewhat unrealistic for actual training scenarios. Nonetheless, such research contributes to the goal of conducting training while conserving native plant communities.

Just as camping and hiking activities serve as surrogate activities for dismounted military training (for the purposes of this report), the use of ORVs by recreationists provides information about potential effects of mounted military training. The damage done to vegetation by ORV use has been documented and discussed by many land managers, especially those in the California Desert, where most ORV use occurs.

Bury, Luckenbach, and Busack (1977) found decreases in shrub abundance due to direct destruction by ORVs, and they used this characteristic to categorize their study plots into Heavy Use, Moderate Use, and Pit areas. Heavy Use areas were defined by direct damage to shrubs, reduced shrub numbers, and no ground cover. Moderate Use areas were defined by high shrub counts but having damaged foliage and soils in between the shrubs. Pit Areas were the most degraded, with no vegetation, highly compacted soils, and lots of trash. Unless properly managed, military staging and assembly areas could reach this same level of degradation.

Lathrop (1983b) reviewed the quantitative evidence of ORV damage in several southwest locations. Plant density decreased between 24 and 91 percent, depending on the plant community in question, the intensity of use, and method of estimation (either from aerial photos or from ground transect surveys). Loss of vegetative cover was measured as 76 to 96 percent in the same studies. In any case, destruction of vegetation is well-documented. In summary, Lathrop contends that perennial vegetation and ORV use are incompatible. The same conclusion might be made for training lands that receive an appreciable level of mounted military training.

The damage wrought by wheeled and tracked vehicles appears to be long-lasting. Thirty-six years after General Patton led mounted training exercises in the Mojave Desert, the impact on vegetation can still be seen and measured. Tracks are still visible where tank training occurred, and the land has 54 percent fewer plants and a 65 percent decrease in plant cover compared to areas not used for training (Lathrop 1983a). In a very different ecosystem, heath was still dead in trails created by 5 and 10 tank passes after 10 years, although no measurable impacts were found in pH or nutrient content, and 1-pass trails had recovered (Beije 1987). These data indicate that a rest-rotation management system for training lands will be ineffective in the Mojave Desert and perhaps for other ecosystems as well.

At installations where winter mounted maneuvers take place, vegetation can be damaged during winter training. Evidence from snowmobile use shows that hardwood and pine saplings are very sensitive to mechanical damage. In one study, 78 percent of the saplings on a trail were damaged by a single pass of a snowmobile. Plants that protrude above the snow are most fragile, and forest species seem more vulnerable than grassland species (Lodico 1973). A much larger tank or Armored Personnel Carrier (APC) would most likely create significant impacts in the winter in a forested ecosystem. However, the Fort McCoy, WI, BA (DA 1993) concludes that winter training is not a risk for the Karner Blue Butterfly or the lupine on which it depends, due to snow cover and restrictions on areas used for winter training.

Impacts on Animals

Wildlife species may be impacted by mounted military training through direct disturbance effects as well as indirect alteration of their habitat. Vertebrates can be disrupted from foraging or reproductive activities due to human presence and the noise generated by training exercises. Predatory birds sometimes desert their nest and/or their territories because of human activity in the vicinity (DA 1975; reviewed in Whitworth 1995). In fact, much evidence has been gathered to indicate that noise and the presence of human activity present serious impacts on some wildlife populations (e.g. Michigan DMA 1994; noise impacts are reviewed by Larkin, Pater, and Tazik 1995). However, a great many species do not suffer negative consequences, so broad generalizations are inappropriate.

Thorough reviews have been recently published on the direct impacts of mounted military training on birds (Gutzwiller and Hayden 1997) and raptors (Whitworth 1995). Gutzwiller and Hayden (1997) found varying behavioral responses of raptors and game birds to vehicle maneuvers. Researchers have measured changes in foraging strategies, home range sizes, home range shifts, flushes from nests, and nest site fidelity (all reviewed in Gutzwiller and Hayden 1997). Some species are less tolerant of training activities than other species, but there is no clear factor known to explain this variation. However, there is accumulating evidence for habituation to predictable and repeated disturbance and human presence in birds (Gutzwiller and Hayden 1997; Whitworth 1995). Evidence for habituation includes nesting success for raptors near hiking trails (reviewed in Whitworth 1995) and for two species near a military strafing area in Oklahoma (Tennesen 1993 cited in Gutzwiller and Hayden 1997). Little research has evaluated impacts to reproductive success or changes in community structure due to direct military disturbance effects (Gutzwiller and Hayden 1997).

Activities that are analogous to mounted military maneuvers were also assessed by Gutzwiller and Hayden (1997) to ascertain potential direct disturbance impacts. Waterfowl, and especially geese, were distressed enough by helicopter overflights to flush; in some cases, normal feeding behavior was significantly disrupted. Raptors and ospreys seemed much less sensitive. Much research found avoidance and flight responses to roadway traffic, but other research found many species habituated to daily traffic (Gutzwiller and Hayden). Overall, Gutzwiller and Hayden concluded that "wheeled vehicles and roads may or may not be disruptive to birds, depending on a species' sensitivity, the seasonal timing and daily regularity of disturbances, and the proximity of disturbances."

Few studies have assessed the direct impacts of disturbance on mammals or other wildlife. The behavior of 16 coyotes during battlefield simulations was evaluated at the Pinon Canyon Maneuver Site in Colorado (Geese, Ronstad, and Mytton 1989). Military activities included APC, tank, truck, and jeep maneuvers; helicopter and jet overflights; and troop encampments. These activities occurred during all times of the day and night. The experimental animals displayed four different responses: no behavioral response, contraction of home range, expansion of home range, and abandonment of home range (compared to control animals who weren't influenced by military training). The responses were related to amount of protective cover and intensity of activity; those with sufficient cover contracted their range when disturbed, while those with little cover either expanded their home range or abandoned their territories altogether (Geese, Ronstad, and Mytton 1989). It is possible that some TES would respond likewise during military training. During breeding season, frequent or dramatic behavioral disturbances could decrease the population's breeding success.

It can be safely assumed that small animals who den, nest, or live exclusively on the ground will suffer physical injury or death from maneuver training. TES that live in shallow dens, such as the San Joaquin kit fox, the indigo snake, and the desert and gopher tortoises, obviously can be killed while undergound. The eggs and young of ground-nesting birds can likewise be destroyed. Unfortunately, the severity of military-related mortality on populations, compared to other sources of mortality, is unknown. For example, accidental burial of kit foxes (from unreported factors) accounted for less than 5 percent of known mortality in the Elk Hills, Kern County, CA. On Camp Roberts in CA, 11 foxes were killed by vehicles (64 percent) or predation (36 percent; EG&G/EM 1991). It was not stated whether the vehicular mortality was associated with mounted maneuver training or other vehicle activity.

All wildlife (and plants, to some degree) are at risk from direct live fire associated with military maneuver training. One study examined the causes of white-tailed

deer mortality on Fort Sill in Oklahoma. Military training accounted for 50 percent of the deer mortality (11 percent from machine gun fire, 39 percent from artillery fire; Dinkines et al. 1992). This type of research has not yet been conducted for TES.

Plant and animal life, including TES, are affected by the alteration of habitat that occurs from military training. Overall reduction of vegetation can lead to a decrease in the prey base for raptors (O'Neil et al. 1990) and other predators. Other such indirect impacts are summarized in Table 1. Basically, maneuver training alters the soil and vegetation so that they resemble a younger stage of development. Species that are adapted to that new environment will be favored, while species who depend on mature soils and vegetation will decline. Unfortunately, many TES depend on wetlands, rare habitats, and/or mature habitats for their survival. Most species that are favored by military training are the same species favored by agricultural practices and urbanization, and are of less conservational concern than TES.

This generalization, however, is not always true. Many TES require habitats that are dependent on fire or soil disturbances (e.g., Red-cockaded Woodpecker, Black-capped Vireo, American Burying Beetle, or the Karner Blue Butterfly). In that case, training-induced changes might maintain valuable TES habitat on post and support

Table 1. Potential changes in soils and vegetation from military maneuver training, and how they may affect wildlife species.

Erosion of upper soil layers; sedimentation
Dens, nests, and food resources of ground-dwelling animals are destroyed. Predators who depend on ground-dwelling animals lose prey base. Fish die from suffocation or from the effects of sedimentation combined with other pollutants. Fish suffer decreased growth rates, decreased spawning. Aquatic vertebrate eggs and larvae are harmed by lower oxygen levels. Wetlands and streams become buried in sediment. Chemical properties of soils and ground waters are changed, water quality declines in caves, which kills cave invertebrates.
Soil compaction, infertility
If soils no longer support plant life, animals lose roosting, nesting, food, and protective resources. If perennial vegetation is replaced by annual weedy species, there will be an increase in seed production from those weedy annuals, which will provide different quantities and qualities of resources for animals.
Destruction of trees and shrubs
The altered habitat will favor different species than otherwise inhabit the area. Increased erosion and compaction (indirect effects as above). Loss of food resources due to decrease in insects, seeds, and small animals. Loss of shade will warm stream temperatures, and can harm aquatic food chain, including vertebrates such as fish.
Adapted from Severinghaus and Severinghaus 1982; and Riggins and Schmidt 1984.

healthy populations of TES, as long as direct mortality from training does not outweigh the beneficial habitat changes. The relationship between the native habitats on the installation, the requirements of the species, and the changes caused by maneuver training determines whether or not (and to what extent) TES will be impacted.

Researchers have documented changes in small mammal and bird populations due to habitat alteration by U.S. Army military training exercises (Table 2). In addition, Gutzwiller and Hayden (1997) thoroughly reviewed the impacts on bird behavior, reproduction, and community structure. The only study that quantitatively measured mechanized recreational impacts examined the effects of repeated ORV use on creosote shrub habitat and the associated bird communities in California (Bury et al. 1977). Moderate- and heavy-use sites had significantly lower avian biomass and fewer breeding species, (the heavy-use site had no breeding birds at all). Similar declines in avian biomass has been consistently documented in intensive maneuver training sites in the United States (Severinghaus, Riggins, and Goran 1979; Severinghaus et al. 1981; and Goran, Radke, and Severinghaus 1983), although intensity of military training was not a significant factor in determining avian abundances in the Netherlands (Thissen and Reijnen 1987). Bury et al. (1977) also documented that many species observed foraging on the ground in the control sites were not seen at all in the moderate-use site. Only one bird was seen foraging on the ground in the heavy-use area (a horned lark [*Eremophila alpestris*], a species that favors bare ground for foraging and breeding; Bury et al. 1977).

Some species prefer the disturbance habitat found where military training occurs. Thus, it is very important to understand how the bird community composition changes due to military activities. Two separate studies have been conducted at Fort Carson, CO, to examine changes in the avian community in response to military training. The first study (Diersing and Severinghaus 1984) found that composition in prairie habitat was affected only slightly by training activities. Overall biomass and abundances were not significantly decreased compared to control sites. However, the biomass of seed-eating, open-field species was higher on the training site, whereas the biomass of omnivorous, open-field species was higher on the control site (Diersing and Severinghaus 1984). In pinyon-juniper forests, the impacts of training on bird communities appear to be more substantial. The inevitable destruction of trees, shrubs, and ground cover in forests leads to major changes in habitat structure. This causes relatively drastic changes in bird abundances and community composition (Severinghaus and Severinghaus 1982). The general result is an increase in open-field, edge, or disturbance-adapted species and a decrease in secretive, woodland and/or ground-feeding species (see Table 2 for

Table 2. Some documented effects of military training exercises on bird and small mammal populations.

Location	Effects	Citation
Fort Carson, CO	**Birds**: In prairie, biomass of seed-eaters increased, biomass of omnivores decreased. In woodland, woodland species declined, while open-field and edge species increased. [a] **Small Mammals**: In prairie, species that prefer sandy soils and eat seeds of weedy plants replaced other species. In woodland, woodland species were replaced by open-field, disturbance-adapted species.[a] Four species declined, while three species were unaffected by training.[b]	[a]Diersing and Severinghaus 1984 [b]Goran, Radke, and Severinghaus 1983
Fort Knox, KY	**Birds**: 60% decrease in biomass. Woodland species declined the most, open-woods, edge species declined, open-field, bushy habitat species increased. Insectivores declined more than seed-eaters. **Small mammals**: Most mammals totally disappeared, but the white-footed mouse increased by 31 times.	Severinghaus, Riggins, and Goran 1979; Severinghaus, Riggins, and Goran 1980
Fort Hood, TX	**Birds**: 40% decrease in biomass. Woodland species were replaced by open-field, fencerow, and edge species. **Small mammals**: Increase in overall abundance of mammals, due to sufficient habitat islands. Silky pocket mouse (at edge of its range) increased due to xeric conditions, sparse vegetation, and abundant weed seeds.	Severinghaus et al. 1981
Fort Lewis, WA	**Birds**: 25% decrease in biomass. Decrease in ground-feeding omnivores. **Small mammals**: In uplands, shrews and voles declined; no change in deer mouse. In lowlands, shrew declined while deer mouse increased.	Severinghaus and Goran 1981
Fort Benning, GA	**Small mammals**: The beach mouse, which is at the edge of its range, increase due to increased bare ground.	Goran, Radke, and Severinghaus 1983
Fort Bliss, TX	**Small mammals**: No significant changes seen in species composition, abundance, or biomass	Goran, Radke, and Severinghaus 1983
Fort Drum, NY	**Small mammals**: All native species disappeared except for the deer mouse.	Goran, Radke, and Severinghaus 1983
Fort Irwin, CA	**Birds**: The high-use training area had decreased avian biomass due to loss of shrubs. Only one species, which inhabits bare ground, was found in the high use area; highly adaptive species or those found in sparsely vegetated areas were seen in the moderate use training areas.[a] **Small mammals**: Training does not seem to affect small mammal populations.[b]	[a]Krzysik 1984 [b]Goran, Radke, and Severinghaus 1983
Fort Polk, LA	**Birds**: Changes in species composition were found, but no clear explanation was apparent. **Small mammals**: Very low populations on entire installation. Four species only seen in control area. One species only in training area (at the edge of its range, adapted to xeric, sparsely vegetated areas).	Goran, Radke, and Severinghaus 1983
Fort Riley, KS	**Small mammals**: Biomass was not reduced, but two species declined. The white-footed mouse increased.	Goran, Radke, and Severinghaus 1983
Fort Stewart, GA	**Small mammals**: Old field mouse populations increased in training area.	Goran, Radke, and Severinghaus 1983

individual citations). Trends such as these are real concerns for TES conservation, since many secretive, forest-interior bird populations are declining. The second research project (Tazik 1991), found only one species for which abundances changed in response to a year of military activity. Grasshopper sparrows (*Ammodramus savannarum*; a prairie species) had declined in the more disturbed areas compared to the least disturbed area. The pinyon-juniper bird community decreased in species richness with disturbance (Tazik 1991).

Gutzwiller and Hayden (1997) cite the following factors influencing the overall impact of training maneuvers on bird populations:

1. changes in vegetation structure, composition, and development due to military maneuvers,
2. the response of birds to changes in vegetation characteristics at many different scales,
3. behavioral changes caused by training can lead to site abandonment or colonization,
4. the total displacement of secretive or sensitive species,
5. the attractiveness of disturbed areas to exotic and/or disturbance-tolerant species, and
6. the seasonal timing of training maneuver activities.

The same criteria also appear to govern the impacts of training on mammals. Small mammal communities generally follow the same pattern as bird communities: species that are adapted to reduced vegetation, bare ground, and/or disturbance are favored, while more sensitive woodland species decline. In addition, the weedy annual plants that flourish in highly disturbed areas provide abundant seed crops that are used by the more common small mammal species. In several cases, all small mammal species disappeared in training areas, except for *Peromyscus* mice, which are highly adaptable (at Fort Knox, Severinghaus, Riggins, and Goran 1979; Fort Drum, NY, and Fort Riley, KS, Goran, Radke, and Severinghaus 1983). At three installations, species that existed at the edge of their range increased in abundance due to training-induced habitat changes. In these cases, the native habitat of the installation did not provide ideal conditions for the species, but training activities led to more bare ground, sparse vegetation, and xeric conditions that benefited the species (see Table 2 for individual accounts). Although the general species replacement pattern holds, exceptions have been documented. At Fort Bliss, TX, and Fort Irwin, CA, training activities don't appear to significantly impact small mammal populations (Goran, Radke, and Severinghaus 1983).

Several efforts have studied the direct disturbance impacts of recreational activities on ungulates. Researchers found increased heart rates in mountain sheep in the presence of humans or traffic, but also saw evidence of habituation to predictable, repetitive stimuli (MacArthur, Johnston, and Geist 1979; MacArthur, Geist and Johnston 1982; Geist, Stemp, and Johnston 1985). Dorrence, Savage, and Huff (1975) found increased movement, increased size of home range, movement of home range center, and decreased numbers in white-tailed deer in relation to snowmobile traffic. On the other hand, Richens and Lavigne (1978) concluded that low to moderate snowmobile use had no observable effect on white-tailed deer behavior, and that snowmobile trails may be beneficial by providing packed pathways that decrease energy expenditure during harsh weather and deep snow. Mule deer will habituate to ORV use if not actively pursued (Yarmology, Bayer, and Geist 1988). When harassed, they increased overall activity levels, increased use of cover, became increasingly sensitive to other vehicles, fled home ranges, increased flight distances, and showed a decrease in reproduction the following spring (Yarmology, Bayer, and Geist 1988).

Unfortunately, not much research is available that documents the indirect, habitat-related impacts of mounted military training exercises on larger mammals, reptiles, amphibians, invertebrates (including insects), or aquatic species. Stones, Downs, and Stewart (1987) stated that elk populations benefitted from habitat changes due to military training and that they used the impact zones when shelling was not conducted. Based on the responses of birds and small mammals to training activities, we can predict that other animals will respond similarly. Those species that are more tolerant of human presence, noise, vehicle activity, erosion, sedimentation, soil compaction, destruction of vegetation, and loss of food resources will be favored in areas where mechanized training occurs, while species that are less tolerant of these effects will decline.

Management and Mitigation Options

Sometimes, maneuver training creates TES habitat and increases TES populations. Often, TES and maneuver training are incompatible. In either case, range management decisions, especially at the planning stage, can support TES conservation or at least reduce the impacts of training activity. Managing for TES on maneuver areas starts with conservation of the soils, surface waters, and native vegetation upon which all species depend (O'Neil et al. 1990).

The most effective way to reduce damage to soils and vegetation is to train on sites that have durable soils, little surface water, and hardy vegetation (Lacey and Severinghaus 1981). To do this, managers must understand the limitations of the

soils on post and have a thorough inventory of the plant communities present. If TES are not compatible with high levels of disturbance, disruption of vegetation, and eroded soils, then the intact habitats of those species may be avoided through long-range coordination between training personnel and natural resource staff. Long, steep slopes dissected by many small channels are prone to erosion, while training on gentle topography can be an effective technique for reducing impacts overall (O'Neil et al. 1990). Training areas should be located where minimal surface waters will be impacted. Such wise placement of training areas will reduce conflict with TES (and other sensitive environmental resources) in the long term.

Impacts on soils and vegetation can be further reduced if intensive or large-scale training events can be scheduled for ecologically appropriate times of the year. Training episodes, especially large-scale battlefield simulations, will be more damaging when the soils are very wet or very dry, or when the weather is extremely stressful to plants (Lacey and Severinghaus 1981). For certain plant communities (e.g., desert or shrublands), the timing of training disturbances can largely mitigate the degree of damage to vegetation by (1) preventing damage during sensitive times, and (2) allowing a recovery/growth period. The results of Wilson's (1988) study of tank maneuvers on Canadian grasslands suggested that traffic restrictions from spring thaw until July 1 could improve the resilience of the grassland up to 400 percent. However, in some environments, such as the arid Fort Irwin, a rest period for recovery alone is not feasible—damage occurs too quickly and recovery takes too long (decades or centuries; Lathrop 1983b).

During maneuver training, it is beneficial if vehicle operators control the vehicle to protect soils and vegetation. Vehicle operators can avoid sensitive natural areas such as wetlands, rare plant communities, and TES habitat by regarding them as dangerous zones (e.g., "mine fields") during field exercises. Troops should not damage vegetation or soils beyond mission-essential actions. Installations have built and maintained a network of roads and tank trails; vehicles should stay on these paths unless they are involved in a cross-country exercise. (Details and further references on trail maintenance are available in Baran et al. 1983). When driving wheeled vehicles in deep mud, straight steering and a steady velocity can minimize damage (Collins 1991). Certain maneuvers, such as neutral-steer turns, cause an inordinate amount of damage to soils; they should be discouraged or prohibited. In Germany, terrain maintenance is a high priority; training areas are equipped with "metalled, terrain-adjusted roads" so training can be accomplished in any weather. Compacted soil layers are penetrated at least every 7 years through a drainage program so that water seeps into the ground instead of running off and causing erosion (Lenz 1987). It is possible that technology being used in Germany could be more widely applied in the United States to reduce erosion impacts.

Military land managers should understand the relationship between erosion and the sedimentation of surface waters (Table 1). Water resources (including aquatic TES) are protected to the extent that erosion is minimized. It is beneficial if military vehicles avoid surface waters. When vehicles cross a stream during an exercise, crossings in deep, fast water should be avoided if possible. Crossings should occur in locations with relatively flat stream banks that have been hardened with additional gravel or geotextiles. Terracing, sediment basins, and vegetation barriers should be used to slow runoff velocities and to reduce sedimentation or sloughing of stream banks (Lacey and Severinghaus 1981). Monitoring of surface water quality and benthic invertebrates, fish, and mussels will suggest trends that indicate a problem.

Despite efforts to minimize the impacts, mounted maneuver training will result in damage to soils and vegetation, and the consequential sedimentation of installation streams. When this occurs, restoration efforts can improve the land condition. For example, old trails and roads can periodically be closed for maintenance and restoration. The most efficient and cost-effective method to repair eroded soils is to establish a durable vegetative ground cover. Whenever possible, native species should be used (EG&G/EM 1991; M. Imlay, Natural Resource Specialist, Army National Guard, professional discussion, 10 March 1995; S. Warren, April 1994). Native plants that provide resources for native animals should be included in the mixture of species used to revegetate damaged soils. If the soil is too compacted for vegetation to survive, or if the topsoil has been removed, the site may require intensive preparation, such as disking, tilling, plowing, fertilizing, etc. Steve Parris (forester, Fort Polk, LA, professional discussion, 25 July 1995), has successfully used exotic species plantings in conjunction with fertilization for 3 years on sites where topsoil has disappeared. If the fertilizer is removed after 3 years, native species are able to recolonize the sites. Details on soil restoration are beyond the scope of this report; however, Baran et al. (1983), Riggins and Schmidt (1984), Vachta and Riggins (1988), Hinchman et al. (1990), and Vachta and Riggins (1990) discuss soil erosion management in depth, and many other Federal and state research and assistance services are available.

Even if soils, waters, and vegetation are reasonably protected, individual TES species may require special consideration, depending on the timing, location, and nature of their life functions. It is common for installations to mark the colonies, nests, burrows, locations, etc. of TES and then make the area, including a buffer zone, off limits to any troop activity (except maybe brief foot patrols). These areas can then be protected from harmful activities (DA 1988; EG&G/EM 1991; USACE 1994). All TES should be monitored annually to evaluate population levels. When

possible, the designation and protection of high-quality TES habitat on the installation will accelerate reaching population goals.

Animal species may require additional management restrictions. Speed limits might be necessary on roads that traverse prime TES habitat (EG&G/EM 1991). Breeding seasons and harsh winter weather put extra stress on animals, so training restrictions might need to be more stringent during these periods. Escape routes or habitat islands provide cover from training disturbances, and provision of such resources may require extra effort. The individual requirements of TES populations must be reevaluated regularly and adjustments made to the management approach, since there is no formula that produces solutions for all species at all times in all places.

Earth-moving Activities

The modern soldier relies on battlefield terrain to provide concealment and protection. The terrain is used and modified by both infantrymen and combat engineers. For example, soldiers dig foxholes and tank pits. Engineers must know how to reduce enemy obstacles, create friendly obstacles, and protect soldiers from enemy fire by altering the terrain (FM 5-100, 1988). All of these activities require movement of massive amounts of many layers of soil. Even the deepest root systems of plants are destroyed.

Impacts on Soils, Vegetation, and Animals

No research has documented the impacts of earth-moving activities on TES populations. However, the consequences can be surmised. Soil is displaced more severely from these activities than from tank maneuvers. Often, fertile top layers of soil become buried under the mineral subsoil, which prohibits the growth of almost all vegetation. Extreme erosion and collapse of the soil structure are likely to occur. Most late successional plants cannot survive in the environment. Animals rarely use these areas, but may need to cross such open areas, which increases their risk of predation.

With time, early successional plants and animals will populate these areas, and they will begin to resemble areas impacted by heavy vehicle traffic. Any species that benefits from heavy disturbances may benefit from military earth-moving activities, after revegetation processes have begun. This would happen only after earth-moving activities ceased long enough for succession to occur.

Management and Mitigation Options

Fort McCoy and many other installations locate engineer activities on a single, designated Engineer Training Site, which limits the area of land affected by earth-moving impacts. This strategy maintains higher quality soils and vegetation throughout the maneuver areas. If an Engineer Training Site was located away from surface waters and away from TES habitat, minimal conflicts would occur. The edges of the site should be aggressively managed and vegetated for erosion control, to reduce sedimentation in adjacent lands and waters.

When earth-moving activities occur in conjunction with large-scale maneuver training (such as foxholes and tank pits), the layers of soil and original land contours should be replaced as carefully as possible (EG&G/EM 1991). If done correctly, vegetation should be able to reestablish during the next growing season. Weedy annuals will most likely be the first colonizers, but their presence will stabilize the soil and encourage other vegetation to take hold.

3 Overall Management Considerations for TES on Military Lands

Populations: Are They Increasing, Decreasing, or Stable?

To conserve TES, the Army must be aware of how activities affect both individuals and populations of protected species. It is easy to understand how a direct hit by artillery fire can kill an individual animal and lead to an impact on the species. However, most impacts are much more subtle and accumulate over longer periods of time. Ecologically, it is important to avoid impacting protected populations to the point where extinction is likely. A population can be defined as a group of animals of the same species that live and interact in close association. Biologists tally births, deaths, emigration, and immigration within a population, to evaluate whether it is increasing, decreasing, or stable in size. Individuals within a population breed with each other, which sometimes leads to unique genetic composition of the population, and possibly unique adaptations to the environment. Just as measures can be developed to protect individuals, measures to enhance the size, growth rates, and genetic variability of listed populations can also be developed.

Viable Populations Require Landscape Management

To protect populations, it is common for biologists and land managers to determine the number of individuals needed to maintain a healthy population through time. This "minimum viable population" will require management at a landscape scale. Species characteristics, such as home range size, critical habitat components, migration patterns, and interactions with other species (i.e., dependency on a pollinator), all help determine habitat requirements of viable populations. For example, animals with larger home ranges will require more habitat than animals with smaller home ranges. Quality of habitat also plays a role—more individuals can coexist in smaller areas if the habitat is of higher quality. Management of the quantity, quality, and distribution of habitat is an essential part of conserving TES (Trame and Tazik, September 1995).

Landscape-scale Impacts to TES Habitat

Fragmentation of TES habitat occurs when large expanses of contiguous habitat is both decreased in size and divided into two or more pieces (Primack 1993). Fragmentation can have many different negative impacts. Plant and animal communities are affected through altered competition, and changes in predation, parasitism, and herbivory patterns (Harris and Silva-Lopez 1992). In addition, populations can become isolated; if one disappears, migrating individuals are unable to reach it and recolonize it. Microenvironments, which are critical habitat components for very small animals and some plants, can be altered through changes in radiation and water fluxes, as well as increased wind effects (Saunders, Hobbs, and Margules 1991). When an area of suitable habitat is fragmented to the degree that it begins to function as an "island," genetic and demographic factors combine to reduce long-term viability of populations (MacArthur and Wilson 1967; Gilpin and Soule 1986; Charlesworth and Charlesworth 1987; Barrett and Kohn 1991). If these processes lead to losses of native species, it can cause simplification of biotic communities until they are dominated by generalist species. This scenario is a common cause of the population declines that lead to a species being listed as threatened or endangered.

Despite the attention given to impacts such as behavioral changes in avifauna, soil compaction, and loss of perennial plant species, it is possible that these impacts may not be as significant to TES populations as the multiple effects of habitat fragmentation by military activity. In other words, the amount and distribution of habitat disruption is probably equal to more important than the nature of the disturbances. This question has not been addressed on military lands.

Management Options To Conserve Populations at the Landscape Scale

An initial understanding of the TES minimum viable population size is needed to conserve populations at the landscape scale. This is an evolving science, which is often limited by a lack of essential, basic ecological data on the species. In rough terms, the estimate of minimum viable population size combined with an assessment of habitat quality leads to a goal for habitat area needed to conserve the species. By maintaining high quality habitat, installations can reduce the land area that becomes formally recognized (and protected) as TES habitat.

Most importantly, when activities that will destroy or radically change habitat are scheduled on post, the potential for fragmentation of habitat can be considered. Master planners can design long-range planning maps that minimize losses in total

TES habitat and habitat fragmentation, thus supporting larger populations on the installation. The larger the installation's entire population, the less devastating are local impacts such as erosion, trampling, or habitat disturbance. By managing for populations on the landscape scale, TES can be conserved more effectively and efficiently.

4 Summary and Conclusions

Although rigorous documentation of maneuver training impacts on TES has not been widespread, there is ample evidence to draw general conclusions about maneuver impacts to soils and vegetation, and to a lesser extent, to plant and animal TES. Both dismounted and mounted training activities create impacts to soils and vegetation, but mounted maneuvers produce more extensive damage and lead to greater erosion and sedimentation. In either case, soils become compacted, and nutrient content, hydrologic flow, and soil structure are altered. Erosion causes movement of soils from the localized training area down ravines and gradients to streams and other wetlands. Native vegetation is usually removed, at least temporarily and sometimes permanently, while weedy, early successional species colonize the bare ground. Grasses and trees are most resistant to destruction, while understory forbs and shrubs are very susceptible.

Populations of TES that are adapted to recently disturbed soils, or open, early successional habitats can be assisted by changes resulting from training activities. Species that depend on intact native ecosystems or are sensitive to human activities can potentially suffer population declines from maneuver training. However, additional, TES-focused research is certainly required before any reliable conclusions about maneuver impacts can be made.

Since impacts are generated at the ecosystem and plant community level, they are difficult to mitigate on training sites. It is important to reduce off-site erosion and sedimentation impacts. The best mitigation is an ecosystem-based management approach, in which landscape level planning can reduce spatial overlap between military training and quality natural habitat for TES. If enough high quality, connected habitat is provided throughout the installation as a whole, the significance of habitat alteration on maneuver training areas can be reduced dramatically.

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Abbreviations and Acronyms

APC	Armored Personnel Carrier
BA	Biological Assessment
BCV	Black-capped vireo
DA	Department of the Army
DMA	(Michigan) Department of Military Affairs
EG&G/EM	EG&G Energy Measurements, Inc.
EIS	environmental impact statement
ESA	Endangered Species Act
FM	Field Manual
FWS	Fish and Wildlife Service
ITAM	Integrated Training Area Management
MACOM	Major Command
NATO CCMS	North Atlantic Treaty Organization Committee on the Challenges of Modern Society
ORV	off-road recreational vehicle
TES	threatened and endangered species
TR	Technical Report
USACE	U.S. Army Corps of Engineers
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